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## **Refurbishing Roof Systems and Roof Terraces on a Major Residential Building Complex**

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### **Keyword**

Roof terraces, green roof systems, up stand heights, plasticizer content, moisture.

### **Abstract**

A major residential building complex with 1,725 apartments where two renovations of the roof systems and terraces have taken place has been surveyed during a period of more than 35 years. The building includes a large number of roof designs in the form of roof terraces, vegetative roof systems and ballasted roof systems.

The roof design is of utmost importance for these buildings where the roof system is not visible and extra care must be taken to ensure watertightness and service life.

This paper presents the experiences gained from the original roof systems and short-lived second roofs, as well as precautions taken to ensure better results during the latest refurbishment. One single faulty detail can spoil a project; therefore, it is crucial that all critical details are analyzed thoroughly during the design and well before launching any specification.

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Both authors have worked with roof system problems for more than 30 years.

## **Background**

Farum Midtpunkt is a major residential building complex built from 1971-73. It has 1,725 apartments of different sizes. All apartments have one or two roof terraces.

All the terraces function as roofs in the apartments below, so the terraces' watertightness is important.

The roof systems and terraces have been monitored during the full service life. They have been renovated twice during the past 37 years.

The first renovation took place in 1990-91. After less than 20 years of service life, major leaks were found in the roof systems and terraces, and after the first renovation, major problems were experienced again less than 10 years later.

After the last renovation in 2001-04, the roof systems and terraces have been monitored closely through yearly inspections. The number of detected leaks now is low, and the service life is expected to be more than 30 years.



Figure 1: View of terraced houses

### The original roof systems and terraces

The original roof systems were a combination of vegetative roof systems and ballasted roof systems as shown in Figure 2.

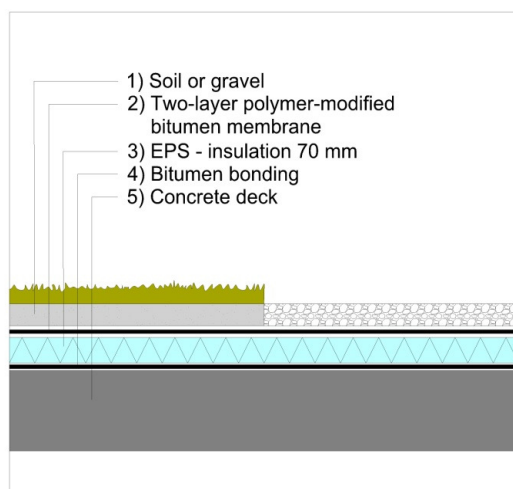


Figure 2: Original vegetative and ballasted roof systems

The roof terraces were built up as shown in Figure 3.

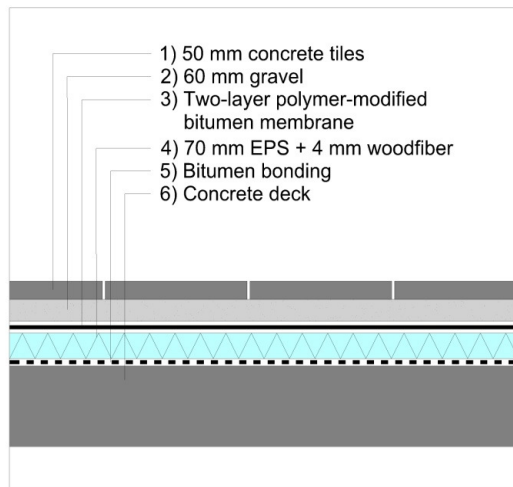


Figure 3: Original roof terraces

The slope of the roof systems and terraces was close to zero, and there was standing water on most roof systems and terraces, though it was hidden under concrete tiles, ballast and vegetation.

The original roof membrane was about 8 mm thick and incorporated fiberglass mats. The roof systems were leaking from day one. The contractor, who had a 10-year warranty, consequently was forced to have two roofing workers fully employed for most of the 10 years to repair the leaks.

The first general survey of the roof systems was carried out in 1981 and showed that nearly 500 of the 1,725 apartments had water penetration from the above roof or roof terrace.

It was difficult to find the origin of the leaks because the membrane was hidden and water could follow different layers and paths in the roof construction. So the leaks never were directly above the water penetration or damaged area.

One of the surveys' conclusions was that the flashings' height was too low, so water could run over the flashings on the roof terraces.

The flashings themselves also were a problem as frost during the winter made the water in the built-up roof system turn into a solid ice cake that expanded and caused pressure on the roofing materials in the flashings, leading to severe cracks.

On the vegetative roof systems, the problem was roots penetrating the roofing materials because they were not root-resistant.

After the end of the warranty period, the building owner repaired many of the roof systems and terraces during a period of seven to eight years but finally gave up. The increasing cost of repairs and tenants' irritation reached a level that demanded a full renovation.

### **The first roof renovation**

The first renovation was carried out in 1990-91. The building owner decided to install a thin insulation with a small slope and a new PVC single-ply membrane with a 15-year warranty against leaks.

As previously mentioned, the original slope of the roofs was nearly zero, and to improve the drainage, a slope of 1:100 for the membrane was established. This was achieved by adding a tapered expanded polystyrene (EPS) insulation directly on the original bitumen membrane as underlayment for the new loose-laid membrane. Consequently, it changed the construction of the roof terraces as shown in Figure 4.

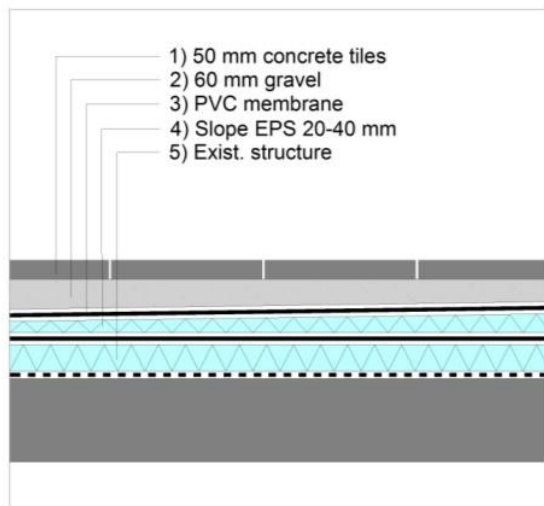


Figure 4: Roof terraces after the first renovation

The vegetative roof systems and ballasted roof systems were changed as shown in Figure 5.

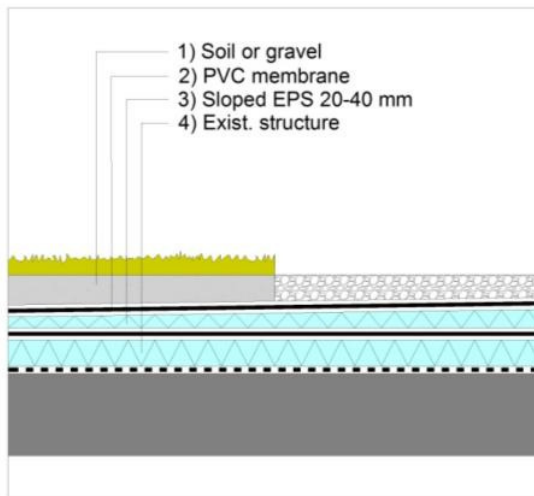


Figure 5: Green roofs after the first renovation

No changes were made to the flashings' height because it would involve changing the windows, doors and wooden facades between the apartments and terraces. Each terrace has two 6 m long façades facing the terrace, and the costs were considered to be too high, even taking into account that it was possible to obtain a 15-year warranty.



Figure 6: Example of flashings between terrace and apartment

The vegetative roof systems were present in two forms. The top of the buildings had vegetative roof systems and ballasted roof systems with no critical flashings or up stands. For some reason, a normal 1.2-mm PVC roof system with polyester reinforcement was chosen and there was no special treatment to ensure resistance to the environment under soil and gravel.

This proved to be a bad decision because a significant part of the PVC membrane's plasticizers seemed to disappear after a few years.





Figure 7: The loss of plasticizers was critical because it caused the membrane to shrink and become brittle.

The biological environment in the soil (bacteria and mold) on top of the membrane probably was the reason for the loss of plasticizers; the plasticizer content fell from 35 percent to 5 percent in 10-12 years. The loss of plasticizer to the EPS insulation was avoided by a separation layer of glass felt.

When the plasticizer content is below 20 percent, the product becomes brittle and cracks readily will occur if people walk on the roofs. The loss of plasticizers also causes the membrane to shrink, which leads to tension in the membrane and creates problems with the flashings, which are pulled off the underlayment.

The rest of the vegetative roof systems were small roof systems situated on each of the apartments, with flashings against the higher parts of the building. These roof systems also were renovated with a PVC membrane but for some reason were covered with an extra layer of PVC foil as a sacrificial layer. In the sacrificial layer, the plasticizers have disappeared, but it has protected the real PVC roof system from plasticizer loss. So these roof systems were not renovated in 2004. However, during

the past few years, a number of problems with these roof systems have emerged, and they now also are being renovated. The main problem is the flashings' inadequate height and the fact that vegetative roof systems generally have increased up to 50 percent in thickness during the past 20 years.

### **The second renovation**

Roof terraces:

In 2000, after a number of investigations and surveys, [the building owner?] realized the problems with the roof systems were not completely solved and a new renovation was necessary.

There were two main problems. The first problem was the PVC roof membrane's poor performance partly because of using an incorrect product and partly because of the membrane's lack of protection from exposure to soil. The other main problems with the terraces were the low height of the up stands. This problem was not solved with the first renovation, where the main focus was to create a new watertight membrane with a 15-year warranty.

Driving rain could lead to water penetration, and during the winter, the snow first would thaw along the up stands while the rest of the roof system still would be frozen. When the water had nowhere to go, it ran over the flashings at the up stands and, in some cases, into the building.

Therefore, the roof terraces needed to be redesigned completely.

The most difficult part was increasing the height of the up stands. After much consideration, it was decided all light facades would be replaced with new facades, new doors and new windows that were 200 mm shorter, making it possible to create new 200-mm higher up stands.

Furthermore, it was deemed important to ensure water readily could get away from the up stands and, therefore, the concrete pavers were placed on footings instead of in gravel as before. The roof's slope also was improved, and the design was changed to a duo roof system (partly inverted roof system) to keep the membrane frost-free during the winter. When using a partly inverted roof system design, the slope can be reduced to 1:100 instead of the normal (in Denmark) 1:40.

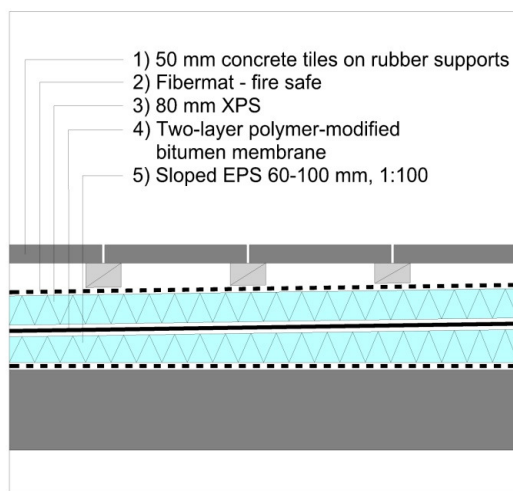


Figure 8: New roof construction of terraces after the second renovation. The roof membrane is protected between two layers of insulation, and water drainage is facilitated by using rubber supports for concrete pavers instead of gravel.

The up stand design was improved by using concrete elements with external insulation instead of wood parts. The flashings thereby were protected from mechanical damage by extruded polystyrene (XPS) insulation with a mortar surface. As an extra safety precaution, gutters were cut in the front of the terrace so water could run out if the drainage system failed.



Figure 9: The membrane is installed in a roof terrace after replacing the two facades to create higher up stands.

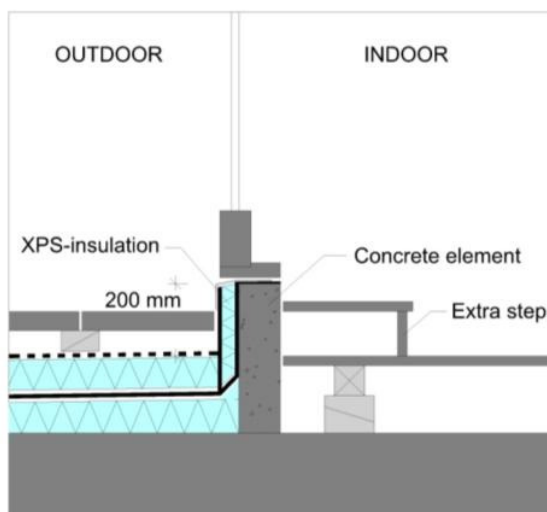


Figure 10: The new 200-mm higher up stands. The up stands are protected from mechanical damage by an external XPS insulation with a render facing.

## The vegetative roof systems and ballasted roof systems

The building owner wanted a 30-year warranty against leaks, and no contractor in Denmark in 2001 was able to offer that for a vegetative roof system or ballasted roof system. Consequently, it was decided to design and install the roof systems as normal warm (compact) roof systems with visible roofing materials that included two layers of SBS-polymer-modified bitumen mechanically fastened to the concrete substrate. The first renovation with EPS and PVC roof systems was removed, but the original roof covering underneath was kept in place. When the EPS was removed, it was extremely wet and contained up to 5 kilograms of water per square meter, which is more than the limit of 1 kilogram of water per square meter set by the Danish Roofing Advisory Board.

The slope was increased to 1:40 (25 mm/1 meter) using a tapered insulation corresponding to the standard for warm roof systems.

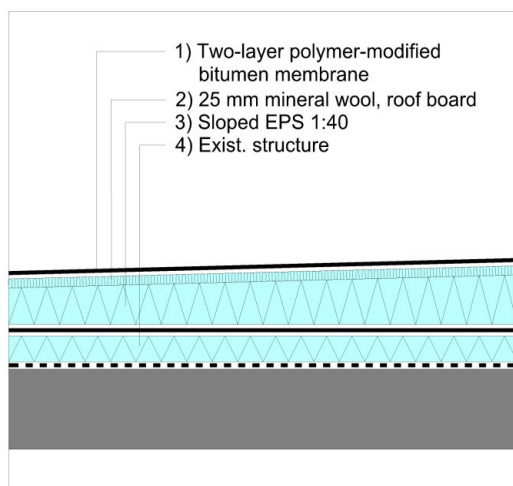


Figure 11: Warm roof system instead of vegetative or ballasted roof systems. The original roof membrane is maintained, the insulation and slope are improved, and the new roof membrane is fully visible.

This changed the buildings' architectural expression. Because only the green edge of the roof systems was visible, the change was fully accepted by the residents association and building owner after some consideration.

The distance between the outlets of the original roof systems were up to 20 meters apart, and new outlets had to be installed to avoid insulation that was too thick. It was not possible to install a new drainage system in the building, so drainage pipes were installed in the insulation to connect the new outlets to the old drainage system. A siphon system was used to make horizontal pipes possible.

This system often is used but is not considered to have the same safety as normal systems with visible pipes. Therefore, the pipes were installed in a special canal of polymer-modified bitumen roofing materials. The canal is equipped with moisture sensors, allowing it to be checked for water from leaks in the pipes. There are more than 350 moisture sensors installed, and each of them is checked once per year. After the first seven years, it has proved to be working because only five small leaks have been discovered.

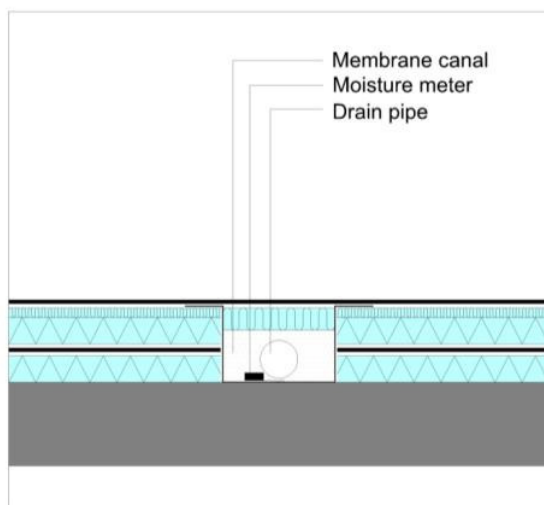


Figure 12: Drainage pipe built into the insulation in a special canal made from the roof membrane

### Small vegetative roof systems

The small vegetative roof systems in the lower levels were not changed during the second renovation because the membrane was not damaged at the time. However, during the past few years, a number of problems have emerged, and the roof systems gradually are being changed to new vegetative roof systems because they have become an important part of the architecture.

To keep the vegetative part away from the flashings and gutters, a roof system with a combination of three roof types was used as shown in Figure 13.

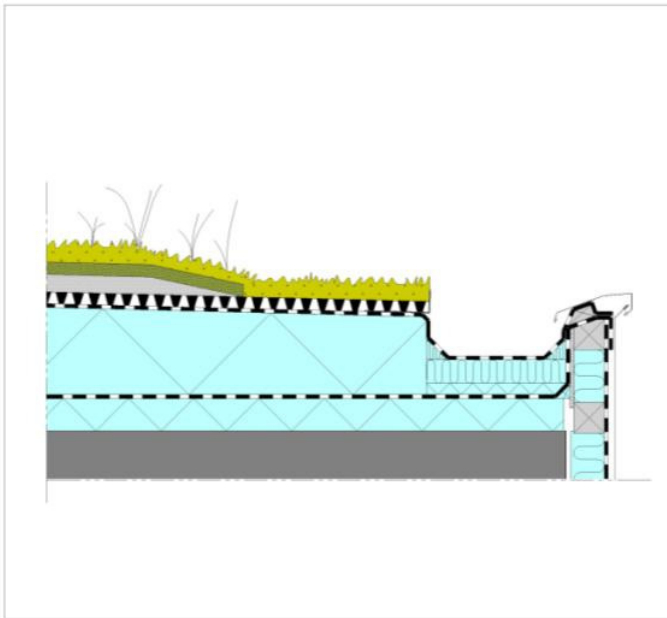


Figure 13: A vegetative roof system designed with sedum in the outer part and grass in the inner part. The gutter is kept free of vegetation.





Figure 14: Small vegetative roof systems are visible from the terraces in the apartments above.

## Conclusions

The past seven years of experiences with the new design of the roof systems and terraces have shown it is possible to construct safe roof systems even on complex buildings such as these. However, the design should include all gained knowledge regarding roof systems and sustainable roof details and combine it with a detailed maintenance plan that includes yearly surveys and necessary repairs.

The design incorporates a warranty of 30 years, allowing a maximum of five of the 1,725 apartments to have leaks per year. If more leaks occur, no maintenance fee is paid for that year.

So far, only up to three leaks have occurred in one year, allowing the contractor his fee every year.





Figure 15: A cozy roof terrace without leaks

The lessons learned are that a warranty cannot solve major problems, such as up stands that are too low, etc. It is vital for the designer to have a solid background regarding roof systems and roofing details, enabling him to make the right decisions before beginning a complicated and large-scale renovation. It especially is important to identify all critical details and find sustainable and buildable solutions with long service lives.